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Technology Overview as part of a Web-based Technical and Regulatory Guidance

Electrocoagulation

1. Introduction

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Electrocoagulation (EC) generally refers to a group of technologies which use an electrical current that coagulates organic constituents and suspended solids in water. The coagulated organics have the ability to adsorb certain ionic constituents, making it possible to separate a flocculent with a majority of the suspended organics and some of the ionic constituents removed. Another variant of this system oxidizes an iron or aluminum anode to form an iron or aluminum hydroxide flocculent which can co-adsorb/co-precipitate some ions. This variant works well only in near-neutral (pH) solutions. Multiple mechanisms have been claimed for removal of contaminants from water.

EC is an active process that involves three major parts:

1. The reaction chamber containing multiple anode and cathode pairs through which the contaminated water passes. The electrodes can be designed as plates, perforated plates, or tubes. They can be composed of different materials, including aluminum, iron, stainless steel, and titanium. A series of reaction chambers can be used, each with different electrode material.
2. The electrical system, composed of control electronics. The current passed to the electrodes is often designed to be alternating (AC). Typically direct current (DC) is required, although using alternating current (AC) technology may prevent formation of an oxide layer on the cathode.
3. A system to dewater the precipitated/coagulated solids. This system could be similar to any used in conventional chemical precipitation processes.

2. Applicability

The Mining Waste Team has found that electrocoagulation may have certain niche applications where the technology may be effective, including near-neutral waters where co-precipitation with iron hydroxide could polish relatively clean waters. Potential applications include the following:

- final treatment and polishing of discharge water from a high-density sludge water treatment plant to remove residual colloidal material and metals.
- pre-treating water prior to [Pressure-Driven Membrane Separation](#) to remove colloidal silica and metals near saturation.
- treating neutral tailings water to remove minor amounts of metals prior to discharge (generally will not be successful treating total dissolved solids (TDS) or sulfate in this type of water)

Prior testing of these applications must be conducted to verify the performance with each water type.

3. Advantages

Advantages of this technology include the following:

- potentially recoverable metals
- reuse of treated effluent

Electrocoagulation is an alternative to chemical precipitation for the removal of dissolved and suspended metals in aqueous solutions (see [Chemical Precipitation Technology Overview](#)). The quantity of sludge produced is lower. The floc generated is larger and heavier and settles out better than in conventional chemical precipitation processes. Since a large thickener is not required, capital costs can also be lower. The effluent generated by electrocoagulation contains no added chemicals and is often of better quality, containing TDS and less colloidal particulates. Reduction of TDS has been reported at 27%–60%, and reduction of total suspended solids can be as great as 95%–99% (Powell Water Systems 2009).

Although electrocoagulation requires energy input, it requires only low currents and can be operated using green technologies such as solar or wind power.

4. Limitations

- high cost

- active
- unproven
- regular replacement of electrodes

The electrocoagulation process is complex. No set configuration is applicable to all needs, and many parameters need to be adjusted for optimal treatment. This includes electrode materials; electrode design; electrode gap; consistent or alternating polarity; current density; flow configuration; retention time; etc. Properties of the wastewater being treated, including conductivity, pH, chemical concentrations, and particle size, also affect the efficiency of the electrocoagulation treatment process.

5. Performance (Results)

For electrocoagulation to be an effective treatment technique, the conductivity of the contaminated water must be high. The treatment has also been demonstrated to work more efficiently when lower concentrations of pollutants are present and when the pH is between 4 and 8 (Adhoun et al. 2004). Electrocoagulation can induce an increase of pH, which may make the treated wastewater alkaline. The induced pH may be as high as 9 or 10. The pH increase is likely the result of excess hydroxyl ions at the cathode due to the reduction of water. The increase in pH is controlled while there are metal ions being precipitated as metal hydroxides. When the concentration of metal ions is low enough, the increase in pH occurs. Electrocoagulation will not treat the majority of impacted water at metal mining sites. Acidic waters are unaffected by electrocoagulation, and most base metal mine water have no organic constituents. When the iron/aluminum anode of the EC system is oxidized in acidic conditions, no flocculent is formed because iron and aluminum are soluble below pH 3. It appears that electrocoagulation does not remove sulfate from sulfate impacted waters.

Although removal rates of metals such as copper and zinc are quite high, the removal of some contaminants such as chromium or silver may require long retention times, depending on the initial concentrations of the pollutants. The removal of chromium and silver is aided by the presence of other metals due to co-precipitation. In the presence of chlorides and organic pollutants, it is possible the electrocoagulation process can oxidize the chlorides and chlorinate the organics into toxic substances.

A mine technology group tested electrocoagulation in 2008 in conjunction with an electrocoagulation technology provider. Mining-influenced water (MIW) was sent to an outside group that was experienced with testing electrocoagulation. While there was some coagulation and reduction of aqueous solutes observed during testing, the testing group was unable to provide a mass balance for their work, and the work was discontinued (Willow Creek Reclamation Committee 2006).

Electro-Pure Systems, Inc. conducted a Superfund Innovative Technology Evaluation (SITE) demonstration in the early 1990s using alternating current electrocoagulation (ACE) (Barkley, Farrell, and Williams 1993). The ACE project demonstrated variable metal removal efficiencies as operating parameters changed. Removal rates were reported at 66%–96% for lead, 90%–100% for copper, 87%–94% for chromium, and 14%–99% for cadmium. The lower removal percentages were seen when treating water containing high concentrations of metals (Barkley, Farrell, and Williams 1993).

An experimental treatment system was conducted at Aachen University, Germany, during 2006. The wastewater tested was from a Serbian mining and smelting complex and contained high concentrations of copper (50 mg/L), aluminum (13 mg/L), and manganese (6 mg/L). The wastewater also had a low pH (4.3) and contained elevated sulfates (560 mg/L). The results of the experiment were favorable, with an increase in pH to 7 and excellent metal removal efficiencies (Cu = 99.9%, Al = 97.7%, Mn = 99.7%). In their technical paper, the authors concluded, "Electrocoagulation may prove to be not only feasible and economically friendly, but also technically and economically superior to conventional technology like chemical precipitation" (Rodriguez et al. 2007).

Electrocoagulation treatment of wastewater from a copper smelting facility was studied by the Central Electrochemical Research Institute in India. The wastewater was characterized by a low pH (0.64–0.88) and contained elevated concentrations of As (1979 mg/L), Cu (164 mg/L), Cd (76 mg/L), and Zn (4565 mg/L). The wastewater was continuously circulated through a flow cell containing a stainless steel plate as the cathode and titanium mesh as the anode. It was noted that the effluent turned a black color due to the precipitation of metal sulfides as sulfate was reduced at the cathode. Maximum removal efficiencies ranged from 73.8% (Cd) to 98.8% (Cu). The overall energy requirement was 10.99 kWh/kg of total heavy metal removed (Basha et al. 2007).

6. Costs

Very little cost information is available. Much of the pilot work that has been conducted using electrocoagulation processes for treatment of metal-containing wastewaters has speculated that costs could be very competitive with traditional chemical precipitation. It is probable that design costs could be quite high, given that the process efficiency is dependent on complex site-specific parameters (see Section 4). A potential cost advantage of the electrocoagulation process is the generation of a lesser amount of sludge. The sludge is generally easier to dewater and may be beneficially recovered.

7. Regulatory Considerations

Metal removal rates indicate that electrocoagulation should be able to achieve regulatory limits. A National Pollutant Discharge Elimination System permit would be required to allow discharge of the treated effluent. Electrocoagulation is not a proven technology for full-scale treatment of mining wastes. This fact may cause difficulties when obtaining regulatory approval/acceptance of its use.

8. Stakeholder Considerations

Several benefits to electrocoagulation may make it acceptable to the public. The ability to recover metals and reuse the effluent makes the electrocoagulation process a good alternative to traditional chemical precipitation technologies. The amount of potentially hazardous sludge generated requiring disposal is also reduced. Green sources of energy could be used to supply the relatively low power demand.

9. Lessons Learned

The electrocoagulation process is site and contaminant specific. Detailed bench and pilot studies would be required prior to implementing the technique.

10. Case Studies

Table 10-1. Case study using electrocoagulation

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Additional Resource: www.finishing.com/4800-4999/4924.shtml

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